

# Trilobites

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## Synopsis

Hirnantian (latest Ordovician) trilobite faunas are surveyed. Some are of restricted diversity, but others are highly diverse. A coeval trilobite fauna from the Gamachian Stage of Anticosti Island is highly diverse, but of different zoogeographical affinity. *Dalmanitina*-*Mucronaspis* occurrences, of putative Silurian age, and usually with other shelly fossils, are discounted. The base of the *acuminatus* Zone may correlate with the first appearance of the trilobite *Acernaspis* in shelly sequences but this awaits confirmation. The systematics of spinose hypostomata within the Dalmanitidae are critically examined, and it is concluded that the concept of *Mucronaspis* requires that spinose hypostomata be present before the generic name is applied. A lectotype of *Mucronaspis danai* (Meek & Worthen 1866) is selected. *Dalmanitina* (*Songxites*) sp. (nov.) from Dob's Linn and *Mucronaspis danai* from Illinois and Missouri are illustrated and described. *Mucronaspis mucronata* and *Acernaspis norvegiensis* are also illustrated, but only briefly discussed. *Acernaspis* (*Acernaspis*) *salmoensis* sp. nov. from Anticosti Island and *Cryptolithus portageensis* sp. nov. from Percé are erected.

## Introduction

The correlation of the base of Silurian, as defined at Dob's Linn, Scotland, using trilobites is difficult as major changes in trilobite faunas occur near, or at, this boundary. In the following, the term Hirnantian (stage) will be used for the strata immediately underlying the *acuminatus* Zone, while the Rhuddanian is the oldest Silurian stage; the Hirnantian, however, has not been approved by the International Union of Geological Sciences.

The disappearance of many trilobite genera and families in the latest Ordovician is well known. Thomas *et al.* (1984: 39) noted that the change from the Ashgill stages Rawtheyan to Hirnantian, in England and Wales, entailed the disappearance of many genera and important Ordovician families such as the agnostids, Trinucleidae, Remopleurididae, Telephinidae, Cyclopygidae, Asaphidae, Dionididae and Phillipsinellidae. Trinucleidae are now known to extend into the Hirnantian (see below). Asaphidae (from Scotland) and Cyclopygidae (from Ireland) were, however, reported from the Hirnantian by Thomas *et al.* (1984: 41, 44). The Hirnantian Stage is reputed for its distinctive impoverished trilobite faunas (see also Lespérance 1974), although the degree and nature of impoverishment is variable from region to region. It would thus appear from these and other data that the major trilobite extinction was near the Rawtheyan-Hirnantian boundary, and not at the base of the Silurian.

Lespérance (1985) attempted to correlate the base of the *acuminatus* Zone with shelly sequences. He noted an ordered succession of appearances of faunas and taxa on Anticosti Island and elsewhere: the *Oulodus? nathani* (conodont) Zone, followed upward by the brachiopods *Zygospiraella*, succeeded by *Stricklandia*, then the trilobite *Acernaspis*, and finally the brachiopod *Virgiana*. Only the appearance of *Acernaspis* seemed to coincide with the base of the *acuminatus* Zone, when compared with the Oslo region (Norway) and the USSR (Kazakhstan and northeast USSR). This *acuminatus*-*Acernaspis* correlation has still to be further tested and confirmed, but no additional data have since come to light to contradict or reaffirm it; it is therefore accepted and used herein.

The recognition of trilobite faunas immediately younger than the base of the *acuminatus* Zone is exceedingly difficult if one excludes *Acernaspis*. Trilobite genera recorded from lowermost Silurian (Rhuddanian) strata consist of holdovers from the Ordovician, and show little change from their ancestors. This apparent lack of change may, however, be due more to the scarcity of monographic treatment, poor preservation and/or, more probably, to infrequent

preservation, than to lack of evolution. *Stenopareia*, aulacopleurids, proetids and calymenids, although apparently common, seem to show little change, or, at least, stratigraphically useful species have not been recognized. Lichids and odontopleurids are scarcer, but still widespread; again stratigraphically useful species are not evident. Homalonotids are even scarcer. All these lowermost Silurian taxa should be reviewed in the light of new material.

Rhuddanian trilobite faunas are perhaps notable by the presence of a limited number of Ordovician holdovers. Examples are *Cyphoniscus* cf. *socialis* (Salter 1853) associated with *Acernaspis* (*A.*) *primaeva* (Clarke 1908) and other trilobites in the Matapédia Group north of Percé (Lespérance in Ayrton *et al.* 1969: 476; Dean 1972), and *Hadromeros* which has been widely reported lately in Rhuddanian strata. Lane (in Thomas *et al.* 1984: 53) reports the presence of *Panarchaeogonus* and *Ceraurinella* in the later Llandovery, so that these otherwise typical Ordovician genera must also have been present in the Rhuddanian. *Sphaerocoryphe* has also been reported from an unspecified level in the Silurian (Thomas & Lane 1984: 62). Thomas *et al.* (1984: 52) state that the following genera are unknown from the Ordovician: *Warburgella* (*Warburgella*), *Harpidella* (*Harpidella*), *Dalmanites*, *Anacaenaspis*, *Podowrinella*, *Calymene* s.s. and *Acanthopyge* (but see below). All in all, early Silurian trilobite faunas appear to be characterized by the absence of specialized Ordovician families and genera, and by the presence of 'generalized' forms, rare new ones (notably *Acernaspis*), and some holdovers from the Ordovician. The 'generalized' trilobites yield in many instances (in the later Silurian and Early Devonian) specialized and distinctive descendants. The early Silurian trilobite faunas thus stand between distinctive and specialized faunas, both older and younger.

This contribution will consequently focus on a certain number of biostratigraphically useful taxa which were abundant, or at least well known, in the latest Ordovician or earliest Silurian.

### Hirnantian and Gamachian trilobite faunas

Lespérance (1974) surveyed Hirnantian brachiopod and trilobite faunas. Some of this is still pertinent, but must be viewed in the light of the recently promulgated *acuminatus* boundary. Subsequent data from the midcontinent of the USA (Amsden 1974), China (Nanjing Institute 1984), Wales (Cocks & Price 1975; Cocks *et al.* 1984), Norway (Brenchley & Cocks 1982), and the USSR (Apollonov *et al.* 1980; Koren *et al.* 1983) have since been added.

Precise correlations of shelly faunas near and at the *acuminatus* boundary are hampered by the lack of continuous thoroughly investigated sections possessing enough elements in common to correlate. The Anticosti (and, accessorially, Percé) and Oslo region sections are at present those that are easiest to correlate, and they permit, in turn, additional correlations with other sections. The basal *Oulodus?* *nathani* Zone occurs in the lower part of member 7 of the Ellis Bay Formation on Anticosti, and this zone also occurs very low in the Solvik and Sælabonn Formations of the Oslo region (Worsley 1982; Lespérance 1985). It is inescapable that the ecologically complex and diverse faunas of the latest Ordovician '5a' and '5b' of the Oslo region (Brenchley & Cocks 1982) must correlate with strata below the lower part of member 7 on Anticosti. Only '5b' (Langøyene and Langåra Formations) is Hirnantian, whereas the lower boundary of the Gamachian (at the base of the Ellis Bay Formation) is older than the base of the Hirnantian (it occurs 34 m above the base of the 130 m thick Birmingham Member in the Percé area, Lespérance, this volume). To compare Hirnantian faunas on Anticosti and the Oslo region, it is necessary to draw the base of the Hirnantian within the Ellis Bay. As no drastic drop in diversity is apparent in the Ellis Bay (as present in the type Rawtheyan-Hirnantian), quite to the contrary, members 1 and 2 are arbitrarily excluded from the following discussion (representing a thickness comparable in proportion to the Percé strata). Pre-*Oulodus?* *nathani* Zone trilobites common to Anticosti and the Oslo region are *Platycoryphe* and *Toxochasmops*. *Calyptaulax*, *Decoroproetus*, *Dicranopeltis*, *Harpidella*, *Illaenus*, *Mucronaspis*, *Panderia* and *Stenopareia* are only known from '5b', whereas *Amphilichas* (two species), *Cyphoproetus*, *Erratencrinurus* (*Celtencrinurus*), *Failleana*, *Hemiarges*, *Isotelus*, *Lichas*, *Nahannia*, *Otarion*, *Paraharpes* and *Sphaerocoryphe* are only known from Anticosti (Bolton 1981; Brenchley &

Cocks 1982; Chatterton *et al.* 1983; and the writer's unpublished data). To compare post-basal *Oulodus? nathani* and pre-*acuminatus* trilobite faunas from the same areas, all '6a' and '6b' occurrences are presumed to predate the first occurrence of *Acernaspis* (this is probably too generous, as it first occurs in the upper half of '6b $\alpha$ ') (data are from Chatterton *et al.* 1983; Helbert *et al.* 1982; and the writer's unpublished data). *Cyphoproetus*, *Diacalymene*, *Harpidella* and *Stenopareia* occur in both areas, but *Amphilichas*, *Astroproetus*, *Failleana*, *Iliaenoides*, *Leonaspis* and *Primaspis* occur only on Anticosti, while *Arctinurus*, *Calymene*, *Dicranopeltis* and *Hadromeros* only in the Oslo region.

From the above survey, it is clear that there are few Hirnantian genera in common between Anticosti and the Oslo region, which suggests significant zoogeographical differences. If one tabulates the genera restricted to either region, throughout the whole Hirnantian, 23 are counted. Of these, 9 can be considered long-ranging, and 11 seem to be typical Ordovician genera at the end of their biozones (*Amphilichas*, *Calyptaulax*, *Erratencrinurus* (*Celtencrinurus*), *Failleana*, *Iliaenus*, *Isotelus*, *Mucronaspis*, *Nahannia*, *Panderia*, *Paraharpes*, *Primaspis*). The remaining three (*Arctinurus*, *Calymene* and *Iliaenoides*) are more typical of the Silurian, and their biozones should consequently be extended downwards. The genera common to both in pre-*Oulodus? nathani* strata are typical Ordovician ones, while those common to both in post-*Oulodus? nathani* strata are long-ranging.

As the nearby Percé area was assuredly on the same platform as Anticosti and it has very little in common with Anticosti (or the Oslo region), one must seek an explanation. The most obvious reason for these differences is ecological control on these faunas, and, particularly, depth of water and temperature. Depth, *per se*, appears insufficient to explain these differences. Water temperature, particularly considered with an upward-moving thermocline (and glaciations?), appears far more plausible an explanation for these zoogeographical differences.

Finally, what does a typical Hirnantian trilobite fauna contain? Benthic Assemblage 6 faunas consist wholly or predominantly of trilobites, and can be composed of few or many taxa, but shallower communities have far fewer trilobites, commonly with abundant brachiopods. Excluding for the purpose of this discussion groups other than trilobites, two distinct trilobite faunas apparently coexisted. A North American type appears evident (Anticosti Island, Ellis Bay Formation; other faunas such as the Mackenzie faunas reported by Chatterton & Ludvigsen 1983, but sparingly developed in view of the profound disconformity between the Ordovician and the Silurian in most places in North America). The typical 'Old World' Hirnantian trilobite fauna can be monospecific to highly diverse, but usually includes *Dalmanitina* or *Mucronaspis* and a homalonotid (*Brongniartella* or *Platycoryphe*). The Oslo region faunas appear to be intermediate between the two. On the other hand, this variation in diversity has also been ascribed to nearness to the center of glaciation (Cocks & Fortey 1986), but the problem appears more complex than that explanation suggests.

### ***Dalmanitina*–*Mucronaspis* taxa near the Ordovician–Silurian boundary**

A bewildering number of species, particularly from China, and variously referred to *Dalmanitina* or *Mucronaspis*, have been reported from strata immediately above or below the previously accepted or assumed Ordovician–Silurian boundary. Apart from the difficult systematics associated with the generic assignment of the various species (a few are discussed at some length below), some of them have been taken as indicative of a Silurian age. These putative Silurian species are: *Mucronaspis danai* (Meek & Worthen 1866), *Dalmanitina hastingsi* (Reed 1915), *D. kosyndensis* Balashova 1966\*, *D. malayensis* Kobayashi & Hamada 1964, *D. brevispina* Temple 1952, *D. nanchengensis* Lu 1957, *D. pamirica* Balashova 1966\* and *D. subduplicata zorbata* Balashova 1966\* [\*: as cited by Kobayashi & Hamada 1971, but primary source unverified by the present author].

It will be shown below that these occurrences are logically assigned to the Ordovician, if one accepts the base of the Silurian as *at the first appearance* of the *acuminatus* Zone. This principle of correlation by first appearances is at the heart of recent stratigraphical practice, and under-



lies the choice of 'golden spikes', as exemplified by the choice of the Silurian–Devonian boundary. If this is followed, strata underlying the *acuminatus* boundary must be assigned to the Ordovician, whatever the sedimentological and/or faunal succession may suggest.

The primary types of *Mucronaspis danai* occur in an erosional channel, assigned to the Leemon Formation, within the Girardeau Limestone of southern Illinois. Conodonts within the same beds as the trilobite are of the *Amorphognathus ordovicicus* fauna (Thompson & Satterfield 1975), of undoubted Ordovician age. Whether this occurrence is of Richmondian or Gamachian age is unknown. The species also occurs in the Edgewood Group of northeastern Missouri (see below).

*Dalmanitina hastingsi* occurs in the lower, or trilobite, unit overlain by the upper or graptolite unit, of the Panghsa-pye Formation (Bender 1983: 63) in Burma. This lower unit is only known from the Panghsa-pye region itself, where it is underlain by the Nyaungbaw Limestone, which is Late Ordovician on the basis of conodonts (Wolfart *et al.* 1984: 41). The graptolites from the upper Panghsa-pye have been assigned to the Rhuddanian (but not as old as the *acuminatus* Zone). The brachiopods from the lower trilobite unit are closely related, if not identical in many cases, to Hirnantian forms (Temple 1965). There is thus no compelling evidence to consider *D. hastingsi* Silurian, and it is here assigned to the Ordovician.

*Dalmanitina malayensis* occurs 1.4 to 1.8 m above the base of the Detrital Band in the Langwaki Islands, above graptolites (Kobayashi & Hamada 1971, 1974) of the *persculptus* Zone. The topmost 4.7 m of the 25 m thick Detrital Band yields graptolites of the upper Rhuddanian–Aeronian. There is consequently no reason to consider *D. malayensis* Silurian.

The primary types of *Dalmanitina brevispina* originate from Watley Gill (Lake District of northern England), from a limestone of the 'Silurian Basal Beds'. Graptolites of the *acuminatus* Zone are welded (*sic*) on top of the 'Basal Beds' (Rickards 1970: 7). There is no evidence for such a zonal assignment for the 'Basal Beds', or strata below them. The same species occurs at Keisley, where it is known from strata below the *persculptus* and *acuminatus* Zones (Wright 1985). Thus both the Keisley and Howgill Fells occurrences of *D. brevispina* are probably Ordovician.

The type material of *Dalmanitina nanchengensis* comes from southern Shaanxi, and it occurs above beds yielding the graptolites *Climacograptus angustus* (Perner, 1895) and *C. mirnyensis* (Obut & Sobolevskaya, 1967) (Lu & Wu 1983). Although *D. nanchengensis* is also known from Sichuan–Guizhou (Szechuan–Kweichow), it is the Shaanxi occurrence that is considered Silurian, on the basis of *C. mirnyensis* which apparently occurs only in the *acuminatus* Zone. Koren *et al.* (1983), however, report that *C. mirnyensis* occurs in the *extraordinarius*, *persculptus* and *acuminatus* Zones, so that *D. nanchengensis* is herein assigned to the Ordovician, because of the lack of diagnostic Silurian elements below it.

Apart from these species, *Mucronaspis mucronata* (Brongniart 1822) has also been claimed to occur in Silurian strata. Disregarding the Scandinavian claims to this age, which are now abandoned in Scandinavia itself, *M. mucronata* has been so cited in the Percé area and in Kazakhstan. Lespérance (this volume) assigns the Percé occurrences to the Hirnantian, while the Kazakhstan occurrences (which cannot be proven to belong to *Mucronaspis*), with other shelly faunas, are in the *persculptus* Zone (Apollonov *et al.* 1980) and so they are pre-Silurian.

*Dalmanitina* sp. occurs in the 'Protatrypa' assemblage, which may reach a level as high as the *Coronograptus cyphus* Zone (Mu 1983: 116–7) in China. In accord with Williams (1983: 611), the base of the *acuminatus* Zone in China is higher than elsewhere, and hence the *Dalmanitina* sp. is perhaps largely pre-Silurian in age; stratigraphical details are not sufficient for a more extended discussion.

The Haverford Mudstone Formation of Wales has yielded in its lower 235 m '*Mucronaspis mucronata*' (quotes are this writer's) and other fossils (Cocks & Price 1975), assigned to the Hirnantian, while the uppermost 140 m yields a rich Rhuddanian fauna, containing, *i.a.*, *Acernaspis* sp. *Brongniartella* sp., *Hadromeros elongatus* (Reed 1931) and *Dalmanites* sp. (Temple 1975); the generic assignment of the dalmanitacean is noteworthy, as are its associated trilobites.

## Systematic Palaeontology

### Family DALMANITIDAE Vogdes, 1890

The distinction between the genera *Dalmanitina* and *Mucronaspis*, as well as the proper assignment and distinctive characters of the numerous species referred to these genera, is difficult. The most recent treatments are by Ingham (1977); Lespérance & Sheehan (1981); Owen (1982); Lu & Wu (1983); Zhu & Wu (1984); Wu (1984); and Cocks & Fortey (1986). Zhu & Wu (1984: 89) were uncertain whether a denticulate posterior hypostomal margin was diagnostic of *Mucronaspis* and, if so, no genuine *Mucronaspis* would be present in China. Hypostomata are conservative evolutionary features and, potentially, powerful phyletic tools, which is a truism in trilobite systematics. As both Destombes (1972) and Ingham (1977) stressed the presence of a denticulate (spinose) hypostoma in *Mucronaspis*, a survey of Ordovician dalmanitacean hypostomata is instructive.

Llanvirn spinose hypostomata are unknown. Three are known from the Llandeilo: *Eodalmanitina macrophtalma* (Brongniart, 1822) (the type species of the genus, Henry 1965: pl. 6, fig. 2), *Crozonaspis struvei* Henry, 1968 (Henry 1980: 149) (but *Crozonaspis morenensis morenensis* Hammann, 1972 (Hammann 1974) is not spinose), and *Phacopidina micheli micheli* (Tromelin, 1877) (Henry 1980: 128). These hypostomata have two small spines (or 'denticles') on their posterolateral border. Caradoc spinose hypostomata also have two spines or denticles: *Kloucekia* (*Phacopidina*) aff. *solitaria* (Barrande, 1846) (of Destombes 1972), *Mucronaspis zagoraensis* Destombes, 1972 (but hypostoma not illustrated), *Dalmanitina* (*Dalmanitina*) *socialis* (Barrande, 1846) (of Struve 1958: pl. 2, fig. 14), the one questionably referred to *Eudolatites* cf. *angelini* (Barrande, 1852) by Struve (1958: 208; pl. 2, fig. 11), as well as the upper Caradoc and Ashgill *Baniaspis globosa* Destombes, 1972. The following Ashgill spinose hypostomata have six spines: *Mucronaspis danai*, *Dalmanitina* (*Mucronaspis*) *termieri* Destombes, 1963 (the type species of the subgenus), and *Mucronaspis mucronata* (Brongniart, 1822). Except for *Crozonaspis*, and the aff. *solitaria* of Destombes (1972; see below), the genera appear to be characterized by these spinose hypostomata, but the hypostomata of most named species are unknown.

The hypostoma of *Dalmanitina mucronata* illustrated by Kielan (1960: pl. 20, fig. 6) is spinose, but it is uncertain if two or six spines are present. Ingham (1977: 113; pl. 25, figs 3–4) described a small holaspis of *Mucronaspis mucronata* which has marginal denticles; he compared this specimen with Kielan's (1960) illustration. Here again, it is not clear how many spines are present; additional data are needed on these unique (?) Polish and northern English occurrences. *Eudolatites* (*Deloitites*) *maiderensis* Destombes, 1972 (the type species of the subgenus) is said to have the beginnings of three small 'denticles', from a worn posterior border of the hypostoma; again more data are needed to confirm this unique type of spinosity. These three occurrences are apparently all Hirnantian.

From the spinose hypostomata previously enumerated, five appear to share common traits: significantly greater width than length (ratio as 4:3), essentially identical shapes (strongly curved posteriorly, lateral margins subparallel), a distinct lateral and posterior border, with two or six denticles or spines. These five are: *Crozonaspis struvei*, *Eodalmanitina macrophtalma*, *Kloucekia* (*Phacopidina*) aff. *solitaria* of Destombes 1972, *Dalmanitina* (*D.*) *socialis* of Struve 1958, and *Mucronaspis termieri*. However, significant nomenclatorial problems exist with two of the above taxa. The lectotype of *Sokhretia solitaria* (Barrande, 1846) (the type of the genus) has been illustrated (Šnajdr 1982), and it is obvious that it is not conspecific with the Moroccan species. This Moroccan aff. *solitaria* falls within the concept of the genus *Phacopidina* of Henry 1980, and is consequently better referred as *Phacopidina* n. sp. The second nomenclatorial problem is, however, far more serious. Barrande's (1852: pl. 26, fig. 21) illustration of the hypostoma of *Dalmanitina socialis* (the type of the genus) shows no denticles, and Struve's (1958) illustration of the species appears to differ only in the presence of these hypostomal denticles. Either hypostomata are sexually dimorphic, they are phenotypically variable, or significant parallel evolution exists within the Dalmanitidae, with consequent polyphyly. Parallel evolution appears much more plausible to this writer, if only to explain the notoriously

difficult systematics associated with some dalmanitaceans. If this explanation is correct, it also necessitates a revision of many previously held taxonomic concepts. Be that as it may, Struve's (1958) *socialis* is better called *Mucronaspis* sp. (nov).

Denticles on hypostomata apparently appeared in the Llandeilo; originally two in number, Ashgill representatives acquired six. Some denticulate hypostomata do not fit into the five taxa quoted above, and one is led to conclude that a separate branch diverged in the Caradoc. These considerations indicate that denticles, or spines, are diagnostic of the hypostomata of *Mucronaspis*, if only because a possible evolutionary path leads to it. If this is the case, the numerous Hirnantian species which are problematically assigned to *Dalmanitina* or *Mucronaspis* should accord with what the type species of the two genera in question possess: non-denticulate in *Dalmanitina*, and denticulate (or spinose) in *Mucronaspis*. Other generic characters of *Mucronaspis* (as opposed to *Dalmanitina*) have been given by Ingham (1977) and Owen (1982). *Mucronaspis* should therefore be interpreted in a strict sense: the diagnostic spinose hypostoma must be identified from a locality before the generic name *Mucronaspis* can be applied to the specimens from the locality. Obviously this course of action creates complications, necessitating in most instances open nomenclature.

Hirnantian, and some pre-Hirnantian, dalmanitaceans referred either to *Dalmanitina* or *Mucronaspis*, and variously assigned to the species *mucronata* Brongniart, 1822, *olini* Temple, 1952, or other more recently erected ones, are almost impossible to assess, because many reported occurrences of these latest Ordovician dalmanitaceans do not illustrate hypostomata, or else the material is more or less severely distorted. A critical look at associated hypostomata is needed to prove or disprove polyphyly in these dalmanitaceans, confirm generic assignments and thus tabulate occurrences, before these trilobites are used for unequivocal dating of the latest Ordovician, as yet impossible with the data at hand. Nonetheless, *Dalmanitina* (*Songxites*) is apparently restricted to the Hirnantian.

#### Subfamily DALMANITININAE Destombes, 1972

SYNONYM. Mucronaspidinae Holloway, 1981.

DISCUSSION. Holloway (1981) distinguished the Mucronaspidinae (*Mucronaspis*, *Eodalmanitina*, *Eudolatites* (*Eudolatites*) Delo, 1935, *E. (Banilites)* Destombes, 1972, *E. (Deloites)*, *Retamaspis* Hammann, 1974 and *?Chattiaspis* Struve, 1958) from the Dalmanitiniinae (*Dalmanitina*, *Crozonaspis*) exclusively on thoracic and pygidial characters. Many characters listed by Holloway (1981) are couched in jargon (well rounded as against not strongly rounded pleural bands; thick and deep as against sharply impressed pleural furrows; shallow and sharply impressed as against sharply impressed interpleural furrows), while other characters differ little in each subfamily (posteriorly elongated posterior projections of thoracic pleural tips, which may be spinose as against rounded; thoracic and pygidial facets (essential to enrollment), either wholly as against essentially non-furrowed). If almost straight pygidial pleural furrows are typical of the Dalmanitiniinae, none of the Chinese *Dalmanitina* are correctly assigned. While pygidial doublures are said to be narrow in the Dalmanitiniinae, and broad in the other subfamily, this feature is still contentious at the specific level, for example in *Stenopareia linnarssoni* (Holm, 1882) (Lane 1979: 16). Of Holloway's criteria between the two subfamilies, perhaps the slope of the pleural bands is distinctive, but the same morphology is recurrent in dalmanitaceans. In any event, this last criterion alone is insufficient for subfamilial distinctness; at best, one could envisage tribal status for spinose hypostomata, but present data are insufficient for this taxonomic status.

#### Genus DALMANITINA Reed, 1905

TYPE SPECIES. *Phacops socialis* Barrande, 1846.

DISCUSSION. Two distinct subgenera are recognized within this genus: *D. (Thuringaspis)* (type *D. (Thuringaspis) osiris* Struve, 1962) (recently discussed by Cocks & Fortey 1986) and *D. (Songxites)* Lin, 1981, which has been accorded generic status by VandenBerg *et al.* 1984, as it



was assigned to the *Mucronaspidinae*. Until further data from Dob's Linn (see below) are presented, subgeneric status is preferable.

Subgenus *SONGXITES* Lin, 1981

TYPE SPECIES. *Dalmanitina (Dalmanitina) wuningensis* Lin, 1974.

DISCUSSION. Siveter & Ingham in Siveter *et al.* 1980 indicated that the reduced palpebral lobe of *D. (Songxites) cellulana* of these authors was the most distinctive feature of an as yet unnamed genus, which would also encompass the Dob's Linn dalmanitacean described below. Lin's (1981) erection of the subgenus *D. (Songxites)* appears to have pre-empted this question as *D. (Songxites) wuningensis*, *D. (Songxites) darraweitensis* Campbell, 1973 (see VandenBerg *et al.* 1984) and *D. (Songxites) cellulana* are very closely related by the possession of reduced palpebral lobes and eye ridges in contact with the axial furrow, opposite (tr.) the 3p lobes. The hypostomata of *D. (Songxites) darraweitensis* and *D. (S.) cellulana* have approximately equal lengths and widths, significant lateral and posterior borders, but are non-spinose, as is apparently *D. (Songxites) sp. (nov.)* discussed below (Siveter & Ingham in Siveter *et al.* 1980: 201). This suggests that an assignment to *Dalmanitina* (as opposed to *Mucronaspis*) is indicated.

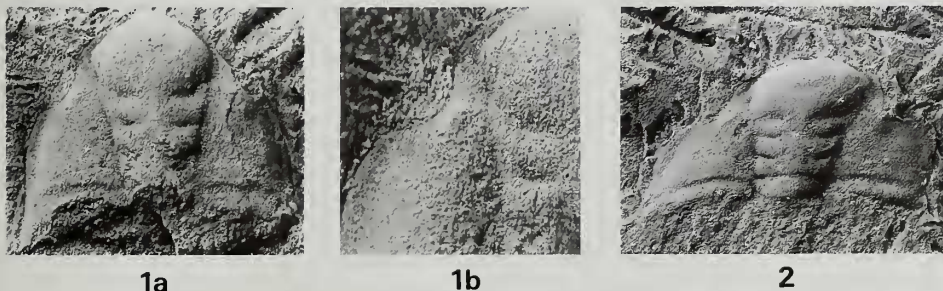
*Dalmanitina (Songxites) sp. (nov.)*

Figs 1–2

1980 *Mucronaspis* sp. Siveter & Ingham in Siveter *et al.*: 200, 201.

MATERIAL. Material collected in 1979 by this writer consists of six complete cranidia (and five less complete ones), three incomplete pygidia, one fragmentary thoracic segment, and a fragmentary hypostoma. It comes from a level 10 cm below the *extraordinarius* Band at Dob's Linn, Scotland. Additional material has been alluded to, including librigenae (Siveter & Ingham in Siveter *et al.* 1980: 201).

DISTINCTIVE ATTRIBUTES. Maximum (tr) width of fixigenae same as maximum width (tr) of frontal glabellar lobe: fixigenae thus very wide. Lateral border furrow shallow, not reaching more incised posterior border furrow. Genal spine short and stout, approximately as long along its length as distal part of posterior border (exsag). Posterior branch of facial suture reaching border at a point (tr) from middle of 3p lobe. Anterior branch of facial suture delimiting a progressively narrower (tr) fixigena, merging into a narrow (exsag) frontal border, absent in front of central third of frontal glabellar lobe. A slightly anteromesially elongated protuberance, opposite (tr) proximal end of 3p furrows, slopes equally in all directions; in so doing, this protuberance reaches the facial suture, which is not dorsally deflected. Protuberance presumably an obsolete palpebral lobe, but librigenae or complete cephalae essential to confirm this;



Figs 1–2 *Dalmanitina (Songxites) sp. (nov.)*. Two differentially preserved inner moulds of cranidia, Fig. 2 showing obvious shearing; from a level 10 cm below the *extraordinarius* Band, Dob's Linn, Scotland. Figs 1a, 1b, BM(NH) It.20480; 1a,  $\times 6.8$ ; 1b, lateral view showing presumed obsolete palpebral lobe and anterior fixigenal area,  $\times 13$  (counterpart, not illustrated, BM(NH) It.20480a, shows an undamaged occipital segment). Fig. 2, BM(NH) It.20481,  $\times 3.5$ .

eyes, presumably, degenerate. 2p furrows transverse, proximal end of 1p furrows slightly posteriorly directed, central part of occipital furrow shallower than distal parts.

Posterior part of hypostoma not preserved, with a distinct lateral border. Pygidial pleural furrows twice as deep and twice as wide as interpleural furrows, anteriormost four pairs evenly curved posterolaterally.

All the material consists of inner and outer moulds; exoskeleton probably very thin and unornamented.

DISCUSSION. The presumed obsolete palpebral lobe, the absence of an eye-ridge (as previously noted by Siveter & Ingham in Siveter *et al.* 1980: 205), and a significant anterior fixigenal area are the unique characters of this species, which should be named when the extant material is brought together.

### Genus *MUCRONASPIS* Destombes, 1963

TYPE SPECIES. *Dalmanitina (Mucronaspis) termieri* Destombes, 1963.

#### *Mucronaspis danai* (Meek & Worthen, 1866)

Figs 3–9

1866 *Dalmania Danæ* Meek & Worthen: 264.

1868 *Dalmanites Danæ* (Meek & Worthen) Meek & Worthen: 363; pl. 6, figs 1a–f.

1917 *Dalmanites danai* (Meek & Worthen) Savage: 147; pl. 8, figs 16, 17.

1940 *Dalmanites danae* (Meek & Worthen); Delo: 40; pl. 3, figs 24, 25.

TYPES. Meek & Worthen's (1868) first illustrations of the species, along with the original description marginally modified, were based on four distinct specimens: a cephalon, a pygidium, an hypostoma, and an incomplete outstretched individual, with a major part of the left side wanting. Two institutions now hold A. H. Worthen's types. The University of Illinois at Urbana-Champaign (UI), under lot X-98 (and 11635), has (a) a complete individual, with the posterior half of the thorax wanting (this specimen has never been illustrated and is not a type), (b) a pygidium (illustrated in Delo 1940: pl. 3, fig. 25; not the original of Meek & Worthen 1868: pl. 6, figs 1d, 1e), and (c) a cephalon claimed to be a syntype of *M. danai* (original of pl. 6, figs 1b, 1c of Meek & Worthen 1868; Hansman & Scott 1967), reillustrated in Delo (1940: pl. 3, fig. 24), but this writer has been unable to examine this specimen recently. Delo (1940) referred to the complete individual above as the holotype, and the pygidium as a paratype (in the text), but in the plate explanations the pygidium and the cephalon are treated as paratypes. This is not, however, considered a designation of a lectotype (which would be invalid in any event).

The Worthen collection in the Illinois State Geological Survey, formerly Illinois State Museum [ISGS(ISM)], holds a syntypic lot of five specimens (Kent 1982): (a) a complete specimen, with much of the left side wanting (original of Meek & Worthen 1868: pl. 6, fig. 1a; 2184-1); (b) a teratological pygidium, with the right pleuron damaged, never illustrated or referred to (2184-2); (c) a cephalon, with most of the right gena missing, never illustrated or referred to (2184-3); (d) a cranidium, with most of the occipital segment broken off, never illustrated or referred to (2184-4); and (e) a pygidium, very probably the original of Meek & Worthen: pl. 6, figs 1d, 1e (2184-5). No hypostoma is thus present in these type collections; two specimens can be identified as syntypes (ISGS 2184-1 and 2184-5), in addition, apparently, to the cephalon in UI X-98. Meek & Worthen's (1866, 1868) measurements refer only to the complete individual (although mention is made in the discussion of an enormous pygidium five inches in length). ISGS 2184-1 is herein designated **lectotype** of *Dalmania danae* (recte *danai*) Meek & Worthen 1866; ISGS 2184-5 becomes a **paralectotype**, as apparently does the cephalon in UI X-98. The syntypic hypostoma appears lost, which is not surprising in view of the adventures of the Worthen collections (Kent 1982). From the preceding, it is clear that this writer accepts as syntypes only those specimens illustrated or referred to in the original description of the species; it is possible that some of the specimens referred to above, but not considered paralectotypes, were indeed syntypes. Formal indication that they were used by



Meek & Worthen (1866) must be presented, however, before they are added to the paralectotype list.

Savage's (1917) drawings of hypotypes (lot UI X-910, toptype cephalon and pygidium) are imprecise, the pygidium particularly so (notably the posterior part of the axis); the upturned posterior spine can, however, be observed on the original.

*Mucronaspis danai* is commonly cited as being erected in 1865, but Hansman & Scott (1967) have shown that the December issue of the Proceedings of the Philadelphia Academy of Natural Sciences was published in 1866. Savage's (1917) publication was also published as an extract in November 1913 (Notice between pp. 66 & 67, Savage 1917), with a different pagination.

**OCCURRENCE.** The syntypes are from an erosional channel of the basal Leemon Formation, along the east bank of the Mississippi river, 5900 ft (1.8 km) NNW of the railroad track and road intersection on the eastern edge of Thebes, Alexander county, Illinois. J. H. Stitt has collected this species from the Late Ordovician Edgewood Group (probably from the Cyrene Member), from a stream outcrop immediately south of 'Ebenezer Church' (Elsberry 15 minute quadrangle, 1934 edition), Lincoln county, 18 mi (29 km) southeast of Louisiana, Missouri.

**ESSENTIAL ATTRIBUTES.** Maximum width of glabella anteriorly, slightly posteriorly of junction of axial and lateral border furrows, 46% of width measured across (tr) occipital segment. 2p furrows essentially transverse, but arched anteriorly, 1p furrows faintly and, more commonly, distinctly posteriorly directed proximally, distal 1p lobes isolated by shallow inner (exsag) furrows, more incised on smaller specimens. Frontal glabellar lobe with auxiliary impression patterns, median posterior impression well developed, stellate, with apparently six rays. Palpebral lobe forms highest part of cephalon; eyes with 37 (or 36?) dorsoventral files, commonly with 10 lenses per file (for a total of approximately 300 lenses), but with as few as 8 lenses per file in smaller specimens. Posterior branch of facial suture reaches marginal furrow at a point across (tr) from 1p furrow, then turns sharply posteriorly across convex border and reaches margin at a point across (tr) occipital furrow. Posterior border furrow deeply incised, meeting marginal furrow, which is the junction of differently dipping border and inner parts of genae (and thus not incised). Frontal border narrow, commonly more or less crushed. On a well preserved toptype specimen, 32 mm long (sag), frontal border consists of an inner portion 0.5 mm long (sag & exsag), separated from an outer portion (librigenae) by the dorsal suture; outer portion ranging from a feather edge (sag) to 2 mm (exsag) anterolaterally of the frontal glabellar lobe. Genal spine half as long as sagittal length of cephalon.

Hypostoma subquadrate with six marginal denticles, incipient on a small individual. Border somewhat convex, significantly longer posteriorly than laterally, set off by distinct furrows. Thoracic segments deeply furrowed, with a stout posteriorly directed distal spine.

Pygidium with 8 (and an incipient ninth) deeply furrowed pleurae, posterior one exsagittal, posterior bands sloping more steeply to interpleural furrow than anterior bands. Pleural and interpleural furrows not reaching margin, former slightly more incised (longer exsag), anterior bands slightly longer than posterior bands across border. Axis with 11 distinct axial rings and a post-axial piece continuing into a posterior spine upturned at approximately 20°; length of spine (sag) same as length (sag) of anteriormost 6 or 7 axial rings, depending on the specimen. Spine and post-axial piece continuing at same height.

Ornamentation poorly known as observed only in the following instances. Pygidium probably smooth, hypostoma with scattered tubercles on anterior lobe of median body, rare to absent on posterior lobe; genae, inward of posterior and marginal furrows, covered with irregular shallow 0.8 mm depressions, lateral cephalic border with granules.

**DISCUSSION.** This species is almost identical to *M. mucronata* dorsally, and may eventually be synonymized with it when the relationships between *M. mucronata* and *M. olini* have been redefined. *M. danai* differs from *M. mucronata* by its tendency to have a more flaring outward (wider, tr) frontal glabellar lobe; maximum width of the glabella in *M. mucronata* is half width across occipital segment. The hypostomata, though, differ more markedly: *M. danai* has fewer

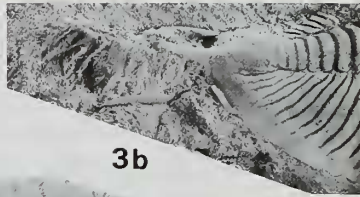
tubercles and its anteriormost marginal denticles are opposite (tr) the proximal end of the median furrow while in *M. mucronata* these denticles are more posterior, nearly opposite (tr) the middle (sag) of the posterior lobe of the median body, and, furthermore, the tubercles tend to coalesce. The median furrow of the hypostoma in *M. danai* is also more incised than in *M. mucronata*.



3a



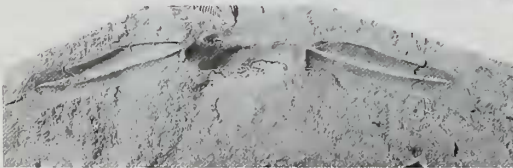
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3b



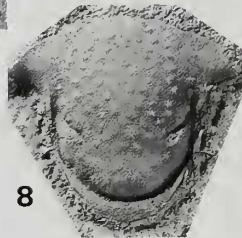
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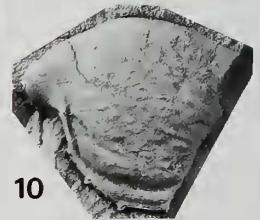
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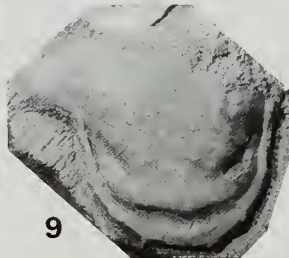
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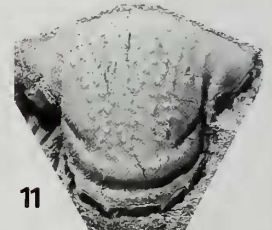
8



10



9



11

*Mucronaspis mucronata* (Brongniart, 1822)  
Figs 10, 11

1822 *Asaphus mucronatus* Brongniart: 24.

1822 *Asaphe mucroné*, *Entomostracites caudatus* de Wahlenberg; Brongniart: 144; pl. 3, fig. 9.

1952 *Dalmanitina mucronata* (Brongniart) Temple: 10; pl. 1, figs 1-3, 5-8; pl. 2, fig. 1.

1981 *Mucronaspis mucronata* (Brongniart) Lespérance & Sheehan: 232; pl. 3, fig. 4; pl. 4, figs 1, 2, 4.

1982 *Mucronaspis mucronata mucronata* (Brongniart); Owen: 271, figs 1A, 1B.

**TYPES.** Lectotype cephalon and paralectotype pygidium selected by Owen (1982), Uppsala University, from the 'Dalmanitina' Beds, Västergötland, Sweden.

**DISCUSSION.** The above synonymy list includes only those illustrated occurrences that can obviously be referred to the species [but the Percé hypostoma included in this list (Lespérance & Sheehan 1981), and reillustrated here for comparison with *M. danai*, with another from the same locality (Figs 10, 11), could conceivably be *M. olini* (Temple 1952)].

Our understanding of this species must still be founded on Temple's (1952) careful study. He has detailed its intraspecific variability and occurrences, but did not record the spinose hypostoma. He distinguished *mucronata* from *olini* almost exclusively on pygidial characteristics, and in fact Lespérance & Sheehan (1981) could not distinguish cephalata of the two species, although this distinction is obvious using the pygidia. Because of this, this writer remains convinced that careful bed by bed collecting may eventually prove or disprove suggestions that *olini* is only a geographical variant (or ecologically controlled) subspecies of *mucronata*, and thus the two species should be kept separate until conclusively proven otherwise.

A complete hypostoma of *M. mucronata kiaeri* (Troedsson, 1918) (Owen 1982, from the Rawtheyan and Hirnantian of the Oslo region, Norway) is unknown, but at least 'a small spine base a short distance out from the sagittal line' is known (Owen 1982: 274), indicating that *kiaeri* is assigned to the proper genus.

Family TRINUCLEIDAE Hawle & Corda, 1847

Trinucleid trilobites occur within the Hirnantian, but they are very uncommon. *Cryptolithus portageensis* sp. nov., described below, occurs in the Percé area. A trinucleid brim fragment has been reported between extensive Hirnantian brachiopod and trilobite faunas and below the *per sculptus* Zone at Keisley, northern England (within unit 9 of Wright 1985: 267). Perhaps more significantly, a fragment of a tretaspid (suggesting the *Tretaspis seticornis* (Hisinger, 1840) group) occurs in northern Wales (in the type region of the Hirnantian) within a brachiopod-

**Figs 3-9** *Mucronaspis danai* (Meek & Worthen, 1866). Figs 3-5, 7, and 9 types and topotypes from north of Thebes, Illinois, Leemon Formation (formerly referred to the Edgewood Group); Figs 6 and 8, from stream outcrop near 'Ebenezer Church' (longitude 90° 53' 19", latitude 39° 12' 57"), northeastern Missouri, Edgewood Group (Late Ordovician). Fig. 3, pygidium, latex cast of outer mould with exoskeleton showing upturned spine, posterior part preserved on original; 3a UMC 16590a, × 1 (outer mould UMC 16590, not illustrated); 3b, lateral view emphasizing spine, × 1. Fig. 4, inner mould, paralectotype pygidium, ISGS 2184-5, × 1.2. Fig. 5, inner mould, incomplete individual, lectotype (herein selected), ISGS 2184-1, × 0.7. Fig. 6, thoracic segment, outer mould with exoskeleton, stout spine on pleural tips can be discerned, UMC 16591, × 1.2. Fig. 7, cephalon, inner mould, UMC 16592, × 0.9 (partial outer mould with exoskeleton shows a complete eye, UMC 16592a, not illustrated). Fig. 8, inner mould, small hypostoma with incipient denticles, UMC 16593, × 3.9. Fig. 9, inner mould, incomplete hypostoma with six denticles, UMC 16594, × 1.4. [ISGS: Illinois State Geological Survey, Champaign, Illinois; UMC: University of Missouri at Columbia, Columbia, Missouri.]

**Figs 10-11** *Mucronaspis mucronata* (Brongniart, 1822). Inner moulds of incomplete hypostomata, Côte de la Surprise Member, White Head Formation, 17 km west-northwest of Percé, Québec. Fig. 10, showing three denticles on left side, posteriormost one present, GSC 83013 (GSC 83013a, counterpart with exoskeleton, not illustrated), × 1.8. Fig. 11, showing a total of four denticles (posteriormost two denticles present on counterpart with exoskeleton, GSC 21909a, not illustrated), GSC 21909, × 1.9.



dominated [*Hirnantia sagittifera* (M'Coy, 1851), *Cryptothyrella* sp. and *Plectothyrella platystrophoides* Temple, 1965] community at the Graig-Wen quarry, Powys (SJ 1018 0930) (J. T. Temple in coll. & personal communication 1985).

Genus *CRYPTOLITHUS* Green, 1832

TYPE SPECIES. *Cryptolithus tessellatus* Green, 1832.

*Cryptolithus portageensis* sp. nov.

Figs 12–14

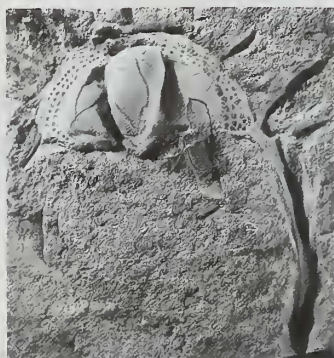
1974 *Cryptolithus* n. sp. Lespérance: 15.

1981 *Cryptolithus* n. sp. Lespérance & Sheehan: pl. 3, fig. 2.

1985 *Cryptolithus* n. sp. Lespérance: 845.

TYPES. Holotype: cephalon Geological Survey of Canada, Ottawa (GSC) 21914 (previously illustrated in Lespérance & Sheehan 1981), paratype cephalon GSC 82988 (ventral view of lower lamella of fringe) and 82989. Also known from an additional six more or less complete cephalon. From a small tributary to the Portage River, 17 km WNW of Percé, Côte de la Surprise Member, White Head Formation, Hirnantian (Lespérance 1974, and this volume, p. 242).

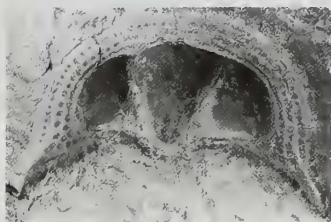
DIAGNOSIS. A species of the genus without glabellar furrows or pits, but with auxiliary impression patterns. The species has complete  $E_1$ ,  $I_1$  and  $I_n$  arcs, but no  $I_2$  arc. Sagittal and immediately adjacent parts of glabella distinctly reticulated.



12a



12b



13



14a



14b

Figs 12–14 *Cryptolithus portageensis* sp. nov. Specimens with exoskeleton, same locality as Figs 10–11. Figs 12a, 12b, holotype, GSC 21914; 12a, showing length of genal spines,  $\times 2.8$ ; 12b, showing well girder on left side,  $\times 4.3$ . Fig. 13, lower lamella of fringe, paratype GSC 82988,  $\times 3$ . Figs 14a, 14b, incomplete cephalon showing ornamentation and glabellar auxiliary impression patterns, paratype GSC 82989; 14a,  $\times 3.4$ ; 14b, lateral view,  $\times 3.8$ .

DESCRIPTION. Sagittal length of cephalon twice maximum width measured across posterior margin. Genal spines slender, flaring outward, then inward distally, 1.5 times length of cephalon. Sagittal tubercle on glabella, slightly in front of glabellar mid-point (excluding occipital segment). Posterior margin of occipital segment entire, not drawn out by a spine, nor possessing a tubercle. Occipital furrow and posterior margin furrow wide (sag, exsag), deep, but occipital shallower. Glabellar furrows or pits absent, but three pairs of darker, slightly impressed auxiliary impression patterns present on sides of glabella, a short distance from axial furrow. Posterior pair comma-shaped, with a more strongly curved portion ventralmost, almost touching occipital furrow, elongated essentially perpendicularly to axial furrow, approximately 1 mm in greatest dimension; second pair circular, approximately 0.6 mm in diameter; anterior pair much as posterior pair, but ventral portion not posteriorly elongated, 0.6 mm along its greatest length, situated essentially transversely to glabellar tubercle (measurements taken from paratype cephalon GSC 82989).

Prominent girder list present on upper lamella of fringe; another list, between  $I_1$  and  $I_n$  only present on posterior half of fringe. Lower lamella of fringe with pseudo-girder between  $I_1$  and  $I_n$ , girder continuous onto genal spine; both girder and pseudo-girder attenuated toward sagittal line. Genae smooth, central and highest part of glabella (sag, exsag) reticulated for a width of approximately 1 mm (tr) (as present on GSC 82989), but ornamentation unknown on anteriormost, and subvertical, portion of glabella.

Following the orientation suggested by Hughes *et al.* (1975: 547), frontal part of fringe horizontal, laterally gentle sloping downward. Arcs  $E_1$ ,  $I_1$  and  $I_n$  complete;  $I_2$  absent. Half fringes with 24–25 pits in  $E_1$ , 18–20 in  $I_1$ , and 18–19 in  $I_n$  arc; 8–10 smaller flange pits present posteriorly, and 6–8 occur along the posterior margin of the fringe.

DIMENSIONS. All the type material is slightly laterally compressed; measurements are in mm.

	Length (sag)	Width across posterior margin
GSC 21914	5.6	11.7 (est.)
GSC 82988	6.3	12.9
GSC 82989	—	11.5 (est.)

DISCUSSION. Glabellar auxiliary impression patterns are known in Caradoc species of *Cryptolithus* (Whittington 1968: pl. 87, figs 6, 10; pl. 88, fig. 11; pl. 89, fig. 1). The low number of pits, particularly the absence of an  $I_2$  arc, as well as a different glabellar ornamentation, distinguish *C. portageensis* sp. nov. from *C. stoermeri* Owen, 1980, from the uppermost Husbergøya Formation (upper Rawtheyan) of the Oslo region. *C. portageensis* sp. nov. is nearest *C. kosoviensis* Marek, 1952 (uppermost Králův Dvůr Formation, Rawtheyan?, Bohemia), which however has a frontally incomplete  $I_n$  arc; only the posterior half of the glabella of *kosoviensis* is reticulated, as is part of the inner posterior cheeks (Příbyl & Vaněk 1969: 104). Hughes *et al.* (1975) have questioned the assignment of *kosoviensis* to *Cryptolithus*, but the similarity of *portageensis* to *kosoviensis* suggests that the Bohemian species is correctly assigned to *Cryptolithus*.

#### Family PHACOPIDAE Hawle & Corda, 1847

Although the genus *Acernaspis* apparently first occurs with the onset of the *acuminatus* Zone, Lespérance & Letendre (1982: 329) have drawn attention to a new genus of this family that first occurs in the Belgian Ashgill.

#### Genus *ACERNASPIS* Campbell, 1967

TYPE SPECIES. *Phacops orestes* Billings, 1860.

REMARKS. *Acernaspis* (subgenus?) *norvegiensis* Lespérance & Letendre, 1982 is herein reillustrated (Fig. 15) to show its distinctness from other species of the genus. It is the only known species within *Acernaspis* which has granules and pustules, many of the latter being perforated. It may be noted here that this species is associated with another species of *Acernaspis* within '6b' of the Asker region, Norway (Lespérance & Letendre 1982: 336).

Subgenus *ACERNASPIS* Campbell, 1967

DIAGNOSIS. Primitive phacopids with continuous vincular furrows, which may be anteriorly shallower. Ornamentation variously with punctae or smooth, but more commonly granulose (Lespérance & Letendre 1981: 199).

REMARK. The use of subgenera within *Acernaspis* has been amply discussed by Lespérance & Letendre 1981, and need not be repeated here.

*Acernaspis (Acernaspis) salmoensis* sp. nov.

Figs 16–19

- 1981 *Acernaspis* sp. Lespérance & Letendre: 197.  
 1982 *Acernaspis* sp. Lespérance & Letendre: 329.  
 1982 *Acernaspis (Acernaspis)* n. sp.? Lespérance & Letendre: 332; pl. 1, fig. 16.  
 1985 *Acernaspis* n. sp. Lespérance: 845.

TYPES. Holotype: GSC 69146, previously illustrated (Lespérance & Letendre 1982). Paratypes: GSC 82990, incomplete cranium; GSC 82991, a pygidium; and GSC 82992, incomplete cephalic doublure.

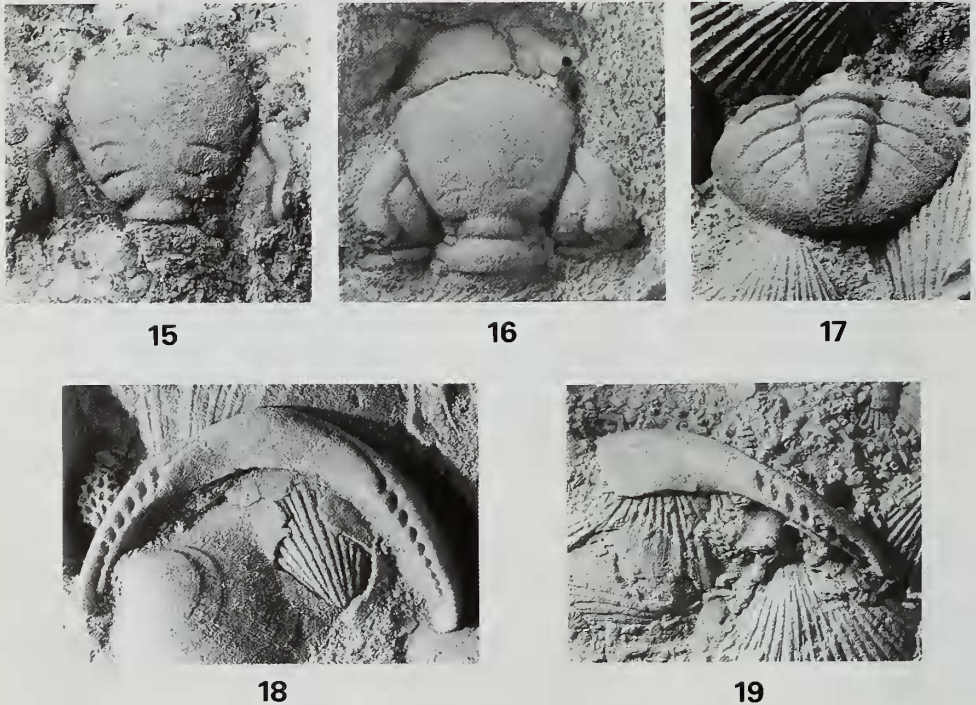


Fig. 15 *Acernaspis* (subgenus?) *norvegiensis* Lespérance & Letendre, 1982. Incomplete cranium with exoskeleton, upper half of '6b' (Solvik Formation: Worsley 1982: 165), Spirodden peninsula, Asker region, Norway; PMO 106-509,  $\times 9.5$ . [PMO: Paleontologisk Museum, Oslo.]

Figs 16–19 *Acernaspis (Acernaspis) salmoensis* sp. nov. Specimens with exoskeleton, Becschie Formation, Anticosti Island, Québec. Fig. 16, incomplete cranium, paratype GSC 82990,  $\times 7.1$ . Fig. 17, pygidium, paratype GSC 82991,  $\times 6.8$ . Fig. 18, cephalic doublure showing vincular furrow, holotype GSC 69146,  $\times 7.3$ . Fig. 19, incomplete cephalic doublure, paratype GSC 82992,  $\times 5.3$ . [GSC: Geological Survey of Canada, Ottawa.]



**OCCURRENCE AND MATERIAL.** Only known from the Rhuddanian Becscie Formation of eastern Anticosti island, Québec. Paratypes from roadside outcrop on northern side of road parallel to, and south of, Salmon River, from a level 4 m above lowermost occurrence of the species. This outcrop extends westward from a stream emptying into the river, and is 960 m west of longitude 62° 18' 00" and 250 m south of latitude 49° 24' 00". This level has yielded approximately 45% of the known material of the species, and the level 4 m below it another 45%. This lowermost level is 45 m above the base of the Becscie Formation (Lespérance 1985: 845). The species also occurs at the 'major falls' along the Salmon River, at 'pool 16' (9.5 km west of the previous locality), and the holotype is from an outcrop along the road leading to Baie de la Tour, 0.8 km north of the main road (approximately 27 km to the northwest of the paratypes; see also Lespérance & Letendre 1982: 334). Extant material of the species includes approximately 10 cephalic doublures, 35 cranidia, 60 pygidia and a few incomplete thoracic segments and librigenae.

**DIAGNOSIS.** A species of *Acernaspis* (*Acernaspis*) with a very shallow anterior vincular furrow and a posterior vincular furrow with dividing walls between fossulae; dorsal sutures functional and ornamentation consisting of microgranules.

**DESCRIPTION.** Glabella expanding forward, widest across frontal glabellar lobe, with a width ratio of 8:5 with width (tr) of occipital segment. 3p furrows bicomposite, distal part impressed, proximal part faintly, as 2p furrows. Distal 1p lobe isolated, below level of 2p lobe and distal part of occipital segment. 1p furrow continuous, poorly incised and shallow sagittally. Occipital furrow incised, continuous. Palpebral furrow incised, extending from axial furrow anteriorly to a point transverse from occipital furrow. Posterior border furrow wide (exag), incised. Palpebral lobes below level of central part of glabella, convex and thus bent downward distally. Dorsal sutures functional. Eyes with a minimum of 14 dorsoventral files, with 3–5 lenses per file.

Anterior part of vincular furrow marginal and ventral, as anterior and anterolateral part of subvertical doublure slopes very steeply posteriorly. Anterolateral section of anterior part of vincular furrow broadly incised, but sagittally barely perceptible and very shallow. Posterior part of vincular furrow scalloped, with 8 or 9 fossulae, with dividing walls between fossulae reaching approximately the mid-point between the bottom of the fossulae and the bounding walls. Anterior half of proximal bounding wall of posterior vincular furrow vertically below adjacent/distal wall, while posterior half of proximal bounding wall of posterior vincular furrow vertically shorter than outer, adjacent distal wall.

Pygidium wider than long (as 8:5), axis with 7 axial rings, not reaching posterior margin. Axial ring furrows transverse, progressively shallower posteriorly. Pleurae with 4 pygidial ribs, very faintly furrowed; distal third of pleural fields unfurrowed. Articulating half-ring cut in middle by facet; furrow between this half-ring and anteriormost rib apparently continuous to margin.

Ornamentation consisting of microgranules (densely packed 0.01–0.04 mm granules, better developed on cephalic doublure, including the anterior part of the vincular furrow), probably modified by surficial weathering.

**DIMENSIONS.** All lengths given are sagittal and all widths are transverse; measurements are in mm.

	GSC 69146	GSC 82992
Width of cephalon	7.3	—
Length of cephalic doublure	1.16	1.91

Paratype pygidium (GSC 82991) has a width of 5.0; its total length is 3.1, which includes a length of 0.20 for the articulating half-ring; length of axis, including articulating half-ring, 2.6. Paratype cranidium (GSC 82990) has a length of 3.8, and widths of 2.2 for the occipital segment and 0.6 for the palpebral lobe.

**DISCUSSION.** The very shallow anterior part of the vincular furrow sets this species apart from all others within the subgenus. The taxon closest to it appears to be *Acernaspis* (*Murphycops*)

*skidmorei* (Lespérance, 1968) (Lespérance & Letendre 1981), which has no anterior vincular furrow and in which the anteriormost part of the cephalic doublure is vertical. *Acernaspis* (*A. salmoensis* sp. nov., in this regard, appears as an ideal ancestor for *A. (Murphycops) skidmorei*, of lower Idwian age. The lowest *Acernaspis* sp. from the Becscie Formation of western Anticosti, near Cap à l'Ours (Lespérance 1985: 845), is too poorly preserved for specific assignment.

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**Note added in page proof.** Additional topotype material of *Cryptolithus portageensis* sp. nov., previously not examined and from a different field collection number, contains three partial and a complete cephalon, as well as a pygidium with a damaged axis. Ornamentation on the central part of the glabella continues on the subventral frontal lobe, but does not reach the fringe. The pygidium has a width to length ratio of 4 : 1, three interpleural furrows not quite reaching the steeply inclined border, and a fourth incipient and posterior one.